THE

RELATION OF LIFE TO OTHER FORCES.

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RELATION OF LIFE TO OTHER FORCES.

An enumeration of theories concerning the nature of life would be beside the purpose of the present short Essay. They are interesting as marks of the way in which various minds have been influenced by the mystery which has always hung about vitality; their destruction is but another warning that any theory we can frame must be considered only a tie for connecting present facts, and one that must yield or break on any addition to the number which it is to bind together.

Before attention had been drawn to the mutual convertibility of the various so-called physical forces—heat, light, electricity, and others—and until it had been shown that these, like the matter through which they act, are limited in amount, and strictly measurable; that a given quantity of one force can produce a certain quantity of another and no more; that a given quantity of combustile material can produce only a given quantity of steam, and this again only so much motive power; it was natural that men's minds should be satisfied with the thought that vital force was some peculiar innate power, unlimited by matter, and altogether independant of structure and organisation. The comparison of life to a flame is probably as early as any thought about life at all. And so long as light and heat were thought to be inherent qualities of certain material which perished utterly in their production, it is not strange that life also should have been reckoned some strange spirit, pent up in the germ, expending itself in growth and development, and finally declining and perishing with the body which it had inhabite.

With the recognition, however, of a distinct correlation between the physical forces, came as a natural consequence a revolution of the commonly accepted theories concerning life also.

The dictum, so long accepted, that life was essentially independent of physical force began to be questioned.

As it is well-nigh impossible to give a definition of life that shall be short, comprehensive, and intelligible, it will be best, perhaps, to take its chief manifestations, and see how far these seem to be dependent on other forces in nature, and how connected with them.

Life manifests itself by birth, growth, development, decline and death; and an idea of life will most naturally arise by taking these events in succession, and studying them individually, and in relation to each other.

When the embryo in a seed awakes from that state, neither life nor death, which is called dormant vitality, and, bursting its envelopes, begins to grow up and develope, it may be said that there is a birth. And so, when the chick escapes from the egg, and when any living form is, as the phrase goes, brought into the world. In each case, however, birth is not the beginning of life, but only the continuation of it under different conditions. To understand the beginning of life in any individual, whether plant or animal, existence must be traced somewhat further back, and in this way an idea gained concerning the nature of the germ, the development of which is to issue in birth.

The germ may be defined as that portion of the parent which is set apart with power to grow up into the likeness of the being from which it has been derived.

The manner in which the germ is separated from the parent does not here concern us. It belongs to the special subject of generation. Neither need we consider apart from others those modes of propagation, as fission and gemmation, which differ more apparently than really from the ordinary process typified in the formation of the seed or ovum. In every case alike, a new individual plant or animal is a portion of its parent; it may be a mere outgrowth or bud, which, if separated, can maintain an independent existence; it may be not an outgrowth but simply a portion of the parent's structure, which has been naturally or artificially cut off, as in the spontaneous or artificial cleaving of

a polype; it may be the embryo of a seed or ovum, as in those cases in which the process of multiplication of different organs has reached the point of separation of the individual more or less completely into two sexes, the mutual conjugation of a portion of each of which, the sperm-cell and the germ-cell, is necessary for the production of a new being. We are so accustomed to regard the conjugation of the two sexes as necessary for what is called generation, that we are apt to forget that it is only gradually in the upward progress of development of the vegetable and animal kingdoms, that those portions of organised matter which are to produce new beings are allotted to two separate individuals. In the least developed forms of life, almost any part of the body is capable of assuming the characters of a separate individual; and propagation, therefore, occurs by fission or gemmation in some form or other. Then, in beings a little higher in rank, only a special part of the body can become a separate being, and only by conjugation with another special part. Still, there is but one parent; and this hermaphrodite-form of generation is the rule in the vegetable and least developed portion of the animal kingdom. At last, in all animals but the lowest, and in some plants, the portions of organised structure specialised for development after their mutual union into a new individual, are found on two distinct beings, which we call respectively male and female.

The old idea concerning the power of growth resident in the germ of the new being, thus formed in various ways, was expressed by saying that a store of dormant vitality was laid up in it, and that so long as no decomposition ensued, this was capable of manifesting itself and becoming active under the influence of certain external conditions. Thus, the dormant force supposed to be present in the seed or the egg was assumed to be the primary agent in effecting development and growth, and to continue in action during the whole term of life of the living being, animal or vegetable, in which it was said to reside. The influence of external forces—heat, light, and others—was noticed and appreciated; but these were thought to have no other connection with vital force than that in some

way or other they called it into action, and that to some extent it was dependent on them for its continuance. They were not supposed to be correlated with it in any other sense than this.

Now, however, we are obliged to modify considerably our notions and with them our terms of expression, when describing the origin and birth of a new being.

To take, as before, the simplest case—a seed or egg. We must suppose that the heat, which in conjunction with moisture is necessary for the development of those changes which issue in the growth of a new plant or animal, is not simply an agent which so stimulates the dormant vitality in the seed or egg as to make it cause growth, but it is a force, which is itself transformed into chemical and vital power. The embryo in the seed or egg is a part which can transform heat into vital force, this term being a convenient one wherewith to express the power which particular structures possess of growing, developing, and performing other actions which we call vital.* Of course the embryo can grow only by taking up fresh material and incorporating it with its own structure, and therefore it is surrounded in the seed or ovum with matter sufficient for nutrition until it can obtain fresh supplies from without. The absorption of this nutrient matter involves an expenditure of force of some kind or other, inasmuch as it implies the raising of simple to more complicated forms. Hence the necessity for heat or some other power before the embryo can exhibit any sign of life. It would be quite as impossible for the germ to begin life without external force as without a supply of nutrient matter. Without the force wherewith to take it, the matter would be useless. The heat, therefore, which in conjunction with moisture is necessary for the beginning of life, is partly expended as chemical power, which causes certain modifications in the nutrient material surrounding the embryo, e.g., the transformation of starch into sugar in the act of germination; partly, it is

* The term "vital force" is here employed for the sake of brevity. Whether it is strictly admissible will be discussed hereafter.

The general term *force* is used as synonymous with what is now often termed *energy*.

transformed by the germ itself into vital force, whereby the germ is enabled to take up the nutrient material presented to it, and arrange it in forms characteristic of life. Thus the force is expended, and thus life begins—when a particle of organised matter, which has itself been produced by the agency of life, begins to transform external force into vital force, or in other words into a power by which it is enabled to grow and develope. This is the true beginning of life. The time of birth is but a particular period in the process of development at which the germ, having arrived at a fit state for a more independent existence, steps forth into the outer world.

The term 'dormant vitality,' must be taken to mean simply the existence of organized matter with the *capacity* of transforming heat or other force into vital or growing power, when this force is applied to it under proper conditions.

The state of dormant vitality is like that of an empty voltaic battery, or a steam-engine in which the fuel is not yet lighted. In the former case no electric current passes, because no chemical action is going on. There is no transformation into electric force, because there is no chemical force to be transformed. Yet, we do not say, in this instance, that there is a store of electricity laid up in a dormant state in the battery; neither do we say that a store of motion is laid up in the steam-engine. And there is as little reason for saying there is a store of vitality in a dormant seed or ovum.

Next to the beginning of life, we have to consider how far its continuance by growth and development is dependent on external force and to what extent correlated with it.

Mere growth is not a special peculiarity of living beings. A crystal, if placed in a proper solution, will increase in size and preserve its own characteristic outline; and even if it be injured, the flaw can be in part or wholly repaired. The manner of its growth, however, is very different from that of a living being, and the process as it occurs in the latter will be made more evident by a comparison of the two cases. The increase of a crystal takes place simply by the laying of material on the surface only, and is unaccompanied by any interstitial change.

This is, however, but an accidental difference. A much greater one is to be found in the fact that with the growth of a crystal there is no decay at the same time, and proceeding with it side by side. Since there is no life there is no need of death—the one being a condition consequent on the other. During the whole life of a living being, on the other hand, there is unceasing change. At different periods of existence the relation between waste and repair is of course different. In early life the addition is greater than the loss, and so there is growth; the reconstructed part is better than it was before, and so there is development. In the decline of life, on the contrary, the renewal is less than the destruction, and instead of development there is degeneration. But at no time is there perfect rest or stability.

It must not be supposed, therefore, that life consists in the capability of resisting decay. Formerly, when but little or nothing was known about the laws which regulate the existence of living beings, it was reasonable enough to entertain such an idea; and, indeed, life was thought to be, essentially, a mysterious power counteracting that tendency to decay which is so evident when life has departed. Now, we know that so far from life preventing decomposition, it is absolutely dependent upon it for all its manifestations.

The reason of this is very evident. Apart from the doctrine of correlation of force, it is of course plain that tissues which do work must sooner or later wear out if not constantly supplied with nourishment; and the need of a continual supply of food, on the one hand, and, on the other, the constant excretion of matter which, having evidently discharged what was required of it, was fit only to be cast out, taught this fact very plainly. But although, to a certain extent, the dependence of vital power on supplies of matter from without was recognised and appreciated, the true relation between the demand and supply was not until recently thoroughly grasped. The doctrine of the correlation of vital with other forces was not understood.

To make this more plain, it will be well to take an instance of transformation of force more commonly known and appreciated. In the steam-engine a certain amount of force is

exhibited as motion, and the immediate agent in the production of this is steam, which again is the result of a certain expenditure of heat. Thus, heat is in this instance said to be transformed into motion, or, in other language, one—molecular—mode of motion, heat, is made to express itself by another—mechanical—mode, ordinary movement. But the heat which produced the vapour is itself the product of the combustion of fuel, or, in other words, it is the correlated expression of another force—chemical, namely, that affinity of carbon and hydrogen for oxygen which is satisfied in the act of combustion. Again, the production of light and heat by the burning of coal and wood is only the giving out again of that heat and light of the sun which were used in their production. For, as it need scarcely be said, it is only by means of these solar forces that the leaves of plants can decompose carbonic acid, &c., and thereby provide material for the construction of woody tissue. Thus, coal and wood being products of the expenditure of force, must be taken to represent a certain amount of power; and, according to the law of the correlation of forces, must be capable of yielding, in some shape or other, just so much as was exercised in their formation. The amount of force requisite for rending asunder the elements of carbonic acid is exactly that amount which will again be manifested when they clash together again.

The sun, then, really, is the prime agent in the movement of the steam-engine, as it is indeed in the production of nearly all the power manifested on this globe. In this particular instance, speaking roughly, its light and heat are manifested successively as vital and chemical force in the growth of plants, as heat and light again in the burning fuel, and lastly by the piston and wheels of the engine as motive power. We may use the term transformation of force if we will, or say that throughout the cycle of changes there is but once force variously manifesting itself. It matters not, so that we keep clearly in view the notion that all force, so far at least as our present knowledge extends, is but a representative, it may be in the same form or another, of some previous force, and incapable like matter of being created afresh, except by the Creator. Much of our knowledge

on this subject is of course confined to ideas and governed by the words with which we are compelled to express them, rather than to actual things or facts; and probably the term force will soon lose the signification which we now attach to it. What is now known, however, about the relation of one force to another, is not sufficient for the complete destruction of old ideas; and, therefore, in applying the examples of transformation of physical force to the explanation of vital phenomena, we are compelled still to use a vocabulary which was framed for expressing many notions now obsolete.

The dependence of the lowest kind of vital existence on external force, and the manner in which this is used as a means whereby life is manifested, have been incidentally referred to more than once when describing the origin of vegetable tissues. The main functions of the vegetable kingdom are construction, and the perpetuation of the race; and the use which is made of external physical force is more simple than in animals. The transformation indeed which is effected, while much less mysterious than in the latter instance, forms an interesting link between animal and crystalline growth.

The decomposition of carbonic acid or ammonia by the leaves of plants may be compared to that of water by a galvanic current. In both cases a force is applied through a special material medium, and the result is a separation of the elements of which each compound is formed. On the return of the elements to their original state of union, there will be the return also in some form or other of the force which was used to separate them. Vegetable growth, moreover, with which we are now specially concerned, resembles somewhat the increase of unorganised matter. The accidental difference of its being in one case superficial, and in the other interstitial, is but little marked in the process as it occurs in the more permanent parts of vegetable tissues. The layers of lignine are in their arrangement nearly as simple as those of a crystal, and almost or quite as lifeless. After their deposition, moreover, they undergo no further change than that caused by the addition of fresh matter, and hence they are not instances of that ceaseless waste and

repair which have been referred to as so characteristic of the higher forms of living tissue. There is, however, no contradiction here of the axiom, that where there is life there is constant change. Those parts of a vegetable organism in which active life is going on are subject, like the tissues of animals, to constant destruction and renewal. But, in the more permanent parts, life ceases with deposition and construction. Addition of fresh matter may occur, and so may decay also of that which is already laid down, but the two processes are not related to each other, and not, as in living parts, inter-dependent. Hence the change is not a vital one.

The acquirement in growth, moreover, of a definite shape in the case of a tree, is no more admirable or mysterious than the production of a crystal. That chloride of sodium should naturally assume the form of a cube is as inexplicable as that an acorn should grow into an oak, or an ovum into a man. When we learn the cause in the one case, we shall probably in the other also.

There is nothing, therefore, in the products of life's more simple forms that need make us start at the notion of their being the products of only a special transformation of ordinary physical force. And we cannot doubt that the growth and development of animals obey the same general laws that govern the formation of plants. The connecting links between them are too numerous for the acceptance of any other supposition. Both kingdoms alike are expressions of vital force, which is itself but a term for a special transformation of ordinary physical force. The mode of the transformation is, indeed, mysterious, but so is that of heat into light, or of either into mechanical motion or chemical affinity. All forms of life are as absolutely dependent on external physical force as a fire is dependent for its continuance on a supply of fuel; and there is as much reason to be certain that vital force is an expression or representation of the physical forces, especially heat and light, as that these are the correlates of some force or other which has acted or is acting on the substances which, as we say, produce them.

In the tissues of plants, as just said, there is but little change,

except such as is produced by additions of fresh matter. That which is once deposited alters but little; or, if the part be transient and easily perishable, the alteration is only or chiefly one produced by the ordinary process of decay. Little or no force is manifested; or, if it be, it is only the heat of the slow oxidation whereby the structure again returns to inorganic shape. There is no special transformation of force to which the term vital can be applied. With construction the chief end of vegetable existence has been attained, and the tissue formed represents a store of force to be used, but not by the being which laid it up. The labours of the vegetable world are not for itself but for animals. The power laid up by the one is spent by the other. Hence the reason that the constant change, which is so great a character of life, is comparatively but little marked in plants. It is present, but only in living portions of the organism, and in these it is but limited. In a tree the greater part of the tissues may be considered dead; the only change they suffer is that fresh matter is piled on to them. They are not the seat of any transformation of force, and therefore, although their existence is the result of living action, they do not themselves live. Force is, so to speak, laid up in them, but they do not themselves spend it. Those portions of a vegetable organism which are doing active vital work—which are using the sun's light and heat, as a means whereby to prepare building material, are, however, the seat of unceasing change. Their existence as living tissue depends upon this fact—upon their capability of perishing and being renewed.

And this leads to the answer to the question, What is the cause of the constant change which occurs in the living parts of animals and vegetables, which is so invariable an accompaniment of life, that we refuse the title of "living" to parts not attended by it? It is because all manifestations of life are exhibitions of power, and as no power can be originated by us; as, according to the doctrine of correlation of force, all power is but the representative of some previous force in the same or another form, so, for its production, there must be

expenditure and change somewhere or other. For the vital actions of plants the light and heat of the sun are nearly or quite sufficient, and there is no need of expenditure of that store of force which is laid up in themselves; but with animals the case is different. They cannot directly transform the solar forces into vital power, they must seek it elsewhere. The great use of the vegetable kingdom is therefore to store up power in such a form that it can be used by animals; that so, when in the bodies of the latter, vegetable organised material returns to an inorganic condition, it may give out force in such a manner that it can be transformed by animal tissues, and manifested variously by them as vital power.

Hence, then, we must consider the waste and repair attendant on living growth and development as something more than these words, taken by themselves, imply. The waste is the return to a lower from a higher form of matter; and, in the fall, force is manifested. This force, when specially transformed by organised tissues, we call vital. In the repair, force is laid up. The analogy with ordinary transmutations of physical force is perfect. By the expenditure of heat in a particular manner a weight can be raised. By its fall heat is returned. The molecular motion is but the expression in another form of the mechanical. So with life. There is constant renewal and decay, because it is only so that vital activity can take place. The renewal must be something more than replacement, however, as the decay must be more than simple mechanical loss. The idea of life must include both storing up of force, and its transformation in the expenditure.

Hence we must be careful not to confound the mere preservation of individual form under the circumstances of concurrent waste and repair, with the essential nature of vitality.

Life, in its simplest form, has been happily expressed by Mr. Savory as a state of dynamical equilibrium, since one of its most characteristic features is continual decay, yet with maintenance of the individual by equally constant repair. Since, then, in the preservation of the equilibrium there is ceaseless change, it is not static equilibrium but dynamical.

Care must be taken, however, not to accept the term in too strict a sense, and not to confound that which is but a necessary attendant on life with life itself. For, indeed, strictly, there is no preservation of equilibrium during life. Each vital act is an advance towards death. We are accustomed to make use of the terms growth and development in the sense of progress in one direction, and the words decline and decay with an opposite signification, as if, like the ebb of the tide, there were after maturity a reversal of life's current. But, to use an equally old comparison, life is really a journey always in one direction. It is an ascent, more and more gradual as the summit is approached, so gradual that it is impossible to say when development ends and decline begins. But the descent is on the other side. There is no perfect equilibrium, no halting, no turning back.

The term, therefore, must be used with only a limited signification. There is preservation of the individual, yet, although it may seem a paradox, not of the same individual. A man at one period of his life may retain not a particle of the matter of which formerly he was composed. The preservation of a living being during growth and development is more comparable, indeed, to that of a nation, than of an individual as the term is popularly understood. The elements of which it is made up fulfil a certain work the traditions of which were handed down from their predecessors, and then pass away, leaving the same legacy to those that follow them. The individuality is preserved, but, like all things handed down by tradition, its fashion changes, until at last, perhaps, scarce any likeness to the original can be discovered. Or, as it sometimes happens, the alterations by time are so small that we wonder, not at the change, but the want of it. Yet, in both cases alike, the individuality is preserved, not by the same individual elements throughout, but by a succession of them.

Again, concurrent waste and repair do not imply of necessity the existence of life. It is true that living beings are the chief instances of the simultaneous occurrence of these things. But this happens only because the conditions under which the

functions of life are discharged are the principal examples of the necessity for this unceasing and mingled destruction and renewal. They are the chief, but not the only instances of this curious conjunction.

A theoretical case will make this plain. Suppose an instance of some permanent structure, say a marble statue. If we imagine it to be placed under some external conditions by which each particle of its substance should waste and be replaced, yet with maintenance of its original size and shape, we obtain no idea of life. There is waste and renewal, with preservation of the individual form, but no vitality. And the reason is plain. With the waste of a substance like carbonate of calcium whose attractions are satisfied, there would be no evolution of force; and even if there were, no structure is present with the power to transform or manifest anew any power which might be evolved. With the repair, likewise, there would be no storing of force. The part used to make good the loss is not different from that which disappeared. There is therefore neither storing of force, nor its transformation, nor its expenditure; and therefore there is no life.

But real examples of the preservation of an individual substance, under the circumstances of constant loss and renewal, may be found, yet without any semblance in them of life.

Chemistry, perhaps, affords some of the neatest and best examples of this. One, suggested by Mr. Shepard, seems particularly apposite. It is the case of trioxide of nitrogen ($N_2 O_3$) in the preparation of sulphuric acid. The gas from which this acid is obtained is sulphurous acid, and the addition of an equivalent of oxygen is all that is required. Sulphurous acid gas, however, cannot take the necessary oxygen directly from the atmosphere, but it can abstract it from trioxide of nitrogen ($N_2 O_3$), when the two gases are mingled. The trioxide, accordingly, by continually giving up an equivalent of oxygen to an equivalent of sulphurous acid, causes the formation of sulphuric acid, at the same time that it retains its composition by continually absorbing a fresh quantity of oxygen from the atmosphere.

In this instance, then, there is constant waste and repair, yet

without life. And here an objection cannot be raised, as it might be to the preceding example, that both the destruction and repair come from without, and are not dependent on any inherent qualities of the substance with which they have to do. The waste and renewal in the last-named example are strictly dependent on the qualities of the chemical compound which is subject to them. It has but to be placed in appropriate conditions, and destruction and repair will continue indefinitely. Force, too, is manifested, but there is nothing present which can transform it into vital shape, and so there is no life.

Hence, our notion of the constant decay which, together with repair, takes place throughout life, must be not confined to any simply mechanical act. It must include the idea, as before said, of laying up of force, and its expenditure—its transformation too, in the act of being expended.

The growth, then, of an animal or vegetable, implies the expenditure of physical force by organised tissue, as a means whereby fresh matter is added to and incorporated with that already existing. In the case of the plant the force used, transformed, and stored up, is almost entirely derived from external sources; the material used is inorganic. The result is a tissue which is not intended for expenditure by the individual which has accumulated it. The force expended in growth by animals, on the other hand, cannot be obtained directly from without. For them a supply of force is necessary in the shape of food derived directly or indirectly from the vegetable kingdom. Part of this force-containing food is expended as fuel for the production of power; and the latter is used as a means wherewith to elaborate another portion of the food, and incorporate it as animal structure. Unlike vegetable structure, however, animal tissues are the seat of constant change, because their object is not the storing up of power, but its expenditure; so there must be constant waste; and if this happen, then for the continuance of life there must be equally constant repair. But, as before said, in early life the repair surpasses the loss, and so there is growth. The part repaired is better than before the loss, and thus there is development.

The definite limit which has been imposed on the duration of life has been already incidentally referred to. Like birth, growth, and development, it belongs essentially to living beings only. Dead structures and those which have never lived are subject to change and destruction, but decay in them is uncertain in its beginning and continuance. It depends almost entirely on external conditions, and differs altogether from the decline of life. The decline and death of living beings are as definite in their occurrence as growth and development. Like these they may be hastened or stayed, especially in the lower forms of life, by various influences from without; but the putting off of decline must be the putting off also of so much life; and, apart from disease, the reverse is true also. A living being starts on its career with a certain amount of work to do—various infinitely in different individuals, but for each well-defined. In the lowest members of both the animal and vegetable creation the progress of life in any given time seems to depend almost entirely on external circumstances; and at first sight it seems almost as if these lowly formed organisms were but the sport of the surrounding elements. But it is only so in appearance, not in reality. Each act of their life is so much expended of the time and work allotted to them; and if, from absence of those surrounding conditions under which alone life is possible, their vitality is stayed for a time, it again proceeds on the renewal of the necessary conditions, from that point which it had already attained. The amount of life to be manifested by any given individual is the same, whether it take a day or a year for its expenditure. Life may be of course at any moment interrupted altogether by disease and death. But supposing it, in any individual organism, to run its natural course, it will attain but the same goal, whatever be its rate of movement. Decline and death, therefore, are but the natural terminations of life; they form part of the conditions on which vital action begins; they are the end towards which it naturally tends. Death, not by disease or injury, is not so much a violent interruption of the course of life, as the attainment of a distant object which was in view from the commencement.

In the period of decline, as during growth, life consists in continued manifestations of transformed physical force; and there is of necessity the same series of changes by which the individual, though bit by bit perishing, yet by constant renewal retains its entity. The difference, as has been more than once said, is in the comparative extent of the loss and reproduction. In decline there is not perfect replacement of that which is lost. Repair becomes less and less perfect. It does not of necessity happen that there is any decrease of the quantity of material added in the place of that which disappears. But although the quantity may not be lessened, and may indeed absolutely increase, it is not perfect as material for repair, and although there may be no wasting, there is degeneration.

No definite period can be assigned as existing between the end of development and the beginning of decline, and chiefly because the two processes go on side by side in different parts of the same organism. The transition as a whole is therefore too gradual for appreciation. But, after some time, all parts alike share in the tendency to degeneration; until at length, being no longer able to subdue external force to vital shape, they die; and the elements of which they are composed simply employ what remnant of power, in the shape of chemical affinity, is still left in them, as a means whereby they may go back to the inorganic world. Of course the same process happens constantly during life; but in death the place of the departing elements is not taken by others.

Here, then, a sharp boundary line is drawn where one kind of action stops and the other begins; where physical force ceases to be manifested except as physical force, and where no further vital transformation takes place, or can in the body ever do so. For the notion of death must include the idea of impossibility of revival, as a distinction from that state of what is called "dormant vitality," in which, although there is no life, there is capability of living. Hence the explanation of the difference between the effect of appliance of external force in the two cases. Take, for examples, the fertile but not yet living egg, and the barren or dead one. Every application of force to

the one must excite movement in the direction of development; the force, if used at all, is transformed by the germ into vital energy, or the power by which it can gather up and elaborate the materials for nutrition by which it is surrounded. Hence its freedom throughout the brooding time from putrefaction. In the other instance, the appliance of force excites only degeneration; if transformed at all, it is only into chemical force, whereby the progress of destruction is hastened; hence it soon rots. To the one, heat is the signal for development, to the other for decay. By one it is taken up and manifested anew, and in a higher form; to the other it gives the impetus for a still quicker fall.

Life, then, does not stand alone. It is but a special manifestation of transformed force. "But if this be so," it may be said —"if the resemblance of life to other forces be great, are not the differences still greater ?"

At the first glance, the distinctions between living organised tissue and inorganic matter seem so great that the difficulty is in finding a likeness. And there is no doubt that these wide differences in both outward configuration and intimate composition have been mainly the causes of the delay in the recognition of the claims of life to a place among other forces. And reasonably enough. For the notion that a plant or an animal can have any kind of relationship in the discharge of its functions to a galvanic battery or a steam engine is sufficiently startling to the most credulous. But so it has been proved to be.

Among the distinctions between living and inorganic matter, that which includes differences in structure and proximate chemical composition has been always reckoned a great one. The very terms organic and inorganic were, until quite recently, almost synonymous with those which implied the influence of life and the want of it. The science of chemistry, however, is a great leveller of artificial distinctions; and many organic substances which, it was supposed, could not be formed without the agency of life are now made directly from inorganic material. The number of organic substances so formed artificially is constantly increasing; and there seems to be no reason for

doubting that all organic substances, even such as albumin, gelatin, and the like, will be ultimately produced without the intermediation of living structure.

The formation of the latter, such an organised structure for instance as a cell or a muscular fibre, is a different thing altogether. There is at present no reason for believing that such will ever be formed by artificial means; and, therefore, among the peculiarities of living force-transforming agents, must be reckoned as a great and essential one, a special intimate structure, apart from mere ultimate or proximate chemical composition, to which there is no close likeness in any artificial apparatus, even the most complicated. This is the real distinction, as regards composition, between a living tissue and an inorganic machine; namely, the difference between the structural arrangement by which force is transformed and manifested anew. The fact that one agent for transforming force is made of albumen or the like, and another of zinc or iron, is a great distinction, but not so essential or fundamental an one as the difference in mechanical structure and arrangement.

In proceeding to consider the difference between what may be called the transformation-products of living tissue, and of an artificial machine, it will be well to take one of the simple cases first—the production of mechanical motion; and especially because it is so common in both.

In one we can trace the transformation. We know, as a fact, that heat produces expansion (steam), and by constructing an apparatus which provides for the application of the expansive power in opposite directions alternately, or by alternating contraction with expansion, we are able to produce motion so as to subserve an infinite variety of purposes. For the continuance of the motion there must be a constant supply of heat, and therefore of fuel.

In the production of mechanical motion by the alternate contractions of muscular fibres we cannot trace the transformation of force at all. We know that the constant supply of force is as necessary in this instance as in the other; and that the food which an animal absorbs is as necessary as the fuel in the

former case, and is analogous with it in function. In what exact relation, however, the latent force in the food stands to the movement in the fibre, we are at present quite ignorant. That in some way or other, however, the transformation occurs, we may feel quite certain.

There is another distinction between the two exhibitions of force which must be noticed. It has been universally believed, almost up to the present time, that in the production of living force the result is obtained by an exactly corresponding waste of the tissue which produces it; that, for instance, the power of each contraction of a muscle is the exact equivalent of the force produced by the more or less complete descent of so much muscular substance to inorganic, or less complex organic shape; in other words,—that the immediate fuel which an animal requires for the production of force is derived from its own substance; and that the food taken must first be appropriated by, and enter into the very formation of living tissue before its latent force can be transformed and manifested as vital power. And here, it might be said, is a great distinction between a living structure and a simply mechanical arrangement such as that which has been used for comparison; the fuel which is analogous to the food of a plant or animal does not, as in the case of the latter, first form part of the machine which transforms its latent energy into another variety of power.

We are not, at present, in a position to deny that this is a real and great distinction between the two cases; but modern investigations in more than one direction lead to the belief that we must hesitate before allowing such a difference to be an universal or essential one. The experiments referred to seem conclusive in regard to the production of muscular power in greater amount than can be accounted for by the products of muscular waste excreted; and it may be said with justice, that there is no intrinsic improbability in the supposed occurrence of transformation of force, apart from equivalent nutrition and subsequent destruction of the transforming agent. Argument from analogy, indeed, would be in favour of the more recent theory as the likelier of the two.

Whatever may be the result of investigations concerning the relation of waste of living tissue to the production of power, there can be no doubt, of course, that the changes in any part which is the seat of vital action must be considerable, not only from what may be called "wear and tear," but, also, on account of the great instability of all organised structures. Between such waste as this, however, and that of an inorganic machine there is only the difference in degree, arising necessarily from diversity of structure, of elemental arrangement, and so forth. But the repair in the two cases is different. The capability of reconstruction in a living body is an inherent quality like that which causes growth in a special shape or to a certain degree. At present we know nothing really of its nature, and we are therefore compelled to express the fact of its existence by such terms as "inherent power," "individual endowment," and the like, and wait for more facts which may ultimately explain it. This special quality is not indeed one of living things alone. The repair of a crystal in definite shape is equally an "individual endowment," or "inherent peculiarity," of the nature of which we are equally ignorant. In the case, however, of an inorganic machine there is nothing of the sort, not even as in a crystal. Faults of structure must be repaired by some means entirely from without. And as our notion of a living being, say a horse, would be entirely altered if flaws in his composition were repaired by external means only; so, in like manner, would our idea of the nature of a steam engine be completely changed had it the power of absorbing and using part of its fuel as matter wherewith to repair any ordinary injury it might sustain.

It is this ignorance of the nature of such an act as reconstruction which causes it to be said, with apparent reason, that so long as the term "vital force" is used, so long do we beg the question at issue—What is the nature of life? A little consideration, however, will show that the justice of this criticism depends on the manner in which the word "vital" is used. If by it we intend to express an idea of something which arises in a totally different manner from other forces—something which,

we know not how, depends on a special innate quality of living beings, and owns no dependence on ordinary physical force, but is simply stimulated by it, and has no correlation with it—then, indeed, it would be just to say that the whole matter is merely shelved if we retain the term "vital force."

But if a distinct correlation be recognised between ordinary physical force and that which in various shapes is manifested by living beings; if it be granted that every act—say, for example, of a brain or muscle—is the exactly correlated expression of a certain quantity of force latent in the food with which an animal is nourished; and that the force produced either in the shape of thought or movement is but the transformed expression of external force, and can no more originate in a living organ without supplies of force from without, than can that organ itself be formed or nourished without supplies of matter;—if these facts be recognised, then the term used in speaking of the powers exercised by a living being is not of very much consequence. We have as much right to use the term "vital" as the words galvanic and chemical. All alike are but the expressions of our ignorance concerning the nature of that power of which all that we call "forces" are various manifestations. The difference is in the apparatus by which the force is transformed.

It is with this meaning that, for the present, the term 'vital force' may still be retained when we wish shortly to name that combination of energies which we call life. For, exult as we may at the discovery of the transformation of physical force into vital action, we must acknowledge not only that, with the exception of some slight details, we are utterly ignorant of the process by which the transformation is effected; but, as well, that the result is in many ways altogether different from that of any other force with which we are acquainted.

It is impossible to define in what respects, exactly, vital force differs from any other. For while some of its manifestations are identical with ordinary physical force, others have no parallel whatsoever. And it is this mixed nature which has hitherto baffled all attempts to define life, and, like a Will-o'-the-wisp, has led us floundering on through one definition

after another only to escape our grasp and show our impotence to seize it.

In examining, therefore, the distinctions between the products of transformations by a living and by an inorganic machine, we have first to recognise the fact, that while in some cases the difference is so faint as to be nearly or quite imperceptible, in others there seems not a trace of resemblance to be discovered.

In discussing the nature of life's manifestations—birth, growth, development, and decline—the differences which exist between them and other processes more or less resembling them, but not dependant on life, have been already briefly considered and need not be here repeated. It may be well, however, to sum up very shortly the particulars in which life as a manifestation of force differs from all others.

The mere acquirement of a certain shape by growth is not a peculiarity of life. But the power of developing into so composite a mass even as a vegetable cell is a property possessed by an organised being only. In the increase of inorganic matter there is no development. The minutest crystal of any given salt has exactly the same shape and intimate structure as the largest. With the growth there is no development. There is increase of size with retention of the original shape, but nothing more. And if we consider the matter a little we shall see a reason for this. In all force-transformers, whether living or inorganic, with but few exceptions—and these are, probably, apparent only—something more is required than homogeneity of structure. There seems to be a need for some mutual dependence of one part on another, some distinction of qualities, which cannot happen when all portions are exactly alike. And here lies the resemblance between a living being and an artificial machine. Both are developments, and depend for their power of transforming force on that mutual relation of the several parts of their structure which we call organization. But here, also, lies a great difference. The development of a living being is due to an inherent tendency to assume a certain form; about which tendency we know absolutely nothing. We recognise the fact, and that is all. The de-

velopment of an inorganic machine—say an electrical apparatus —is not due to any inherent or individual property. It is the result of a power entirely from without; and we know exactly how to construct it.

Here, then, again, we recognise the compound nature of a living being. In structure it is altogether different from a crystal —in inherent capacity of growth into definite shape it resembles it. Again, in the fact of its organisation it resembles a machine made by man: in capacity of growth it entirely differs from it. In regard, therefore, to structure, growth, and development, it has combined in itself qualities which in all other things are more or less completely separated.

That modification of ordinary growth and development called generation, which consists in the natural production and separation of a portion of organised structure, with power itself to transform force so as therewith to build up an organism like the being from which it was thrown off, is another distinctive peculiarity of a living being. We know of nothing like it in the inorganic world. And the distinction is the greater because it is the fulfilment of a purpose, towards which life is evidently from its very beginning, constantly tending. It is as natural a destiny to separate parts which shall form independent beings as it is to develop a limb. Hence it is another instance of that carrying out of certain projects, from the very beginning in view, which is so characteristic of things living and of no other.

It is especially in the discharge of what are called the animal functions that we see vital force most strangely manifested. It is true that one of the actions included in this term—namely, mechanical movement—although one of the most striking, is by no means a distinctive one. For it must be remembered that one of the commonest transformations of physical force with which we are acquainted is that of heat into mechanical motion, and that this may be effected by an apparatus having itself nothing whatever to do with life. The peculiarity of the manifestation in an animal or vegetable is that of the organ by which it is effected, and the manner in which the transformation takes place, not in the ultimate result. The mere fact of an animal's

possessing capability of movement is not more wonderful than the possession of a similar property by a steam engine. In both cases alike, the motion is the correlative expression of force latent in the food and fuel respectively; but in one case we can trace the transformation in the arrangement of parts, in the other we cannot.

The consideration of the products of the transformation of force effected by the nervous system would lead far beyond the limits of the present essay. But although the relation of mind to matter is so little known that it is impossible to speak with any freedom concerning such correlative expressions of physical force as thought and other nerve-products, still it cannot be doubted that they are as much the results of transformation of force as the mechanical motion caused by the contraction of a muscle. But here the mystery reaches its climax. We neither know how the change is effected, nor the nature of the product, nor its analogies with other forces. It is therefore better, for the present, to confess our ignorance, than, with the knowledge which we have lately gained, to build up rash theories, serving only to cause that confusion which is worse than error.

It may be said, with perfect justice, that even if the foregoing conclusions be accepted, namely, that all manifestations of force by living beings are correlative expressions of ordinary physical force, still the argument is based on the assumption of the existence of the apparatus which we call living organised matter, with power not only to use external force for its own use in growth, development, and other vital manifestations, but for that modification of these powers which consists in the separation of a part that shall grow up into the likeness of its parent, and thus continue the race. We are therefore, it may be added, as far as ever from any explanation of the origin of life. This is of course quite true. The object of the present paper, however, is only to deal with the now commonly accepted views regarding the relations of life, as it now exists, to other forces. The manner of creation of the various kinds of organised matter, and the source of those of its qualities which from our ignorance we call inherent, are different questions altogether.

To say that of necessity the power to form living organised matter will never be vouchsafed to us; that it is only a mere materialist who would believe in such a possibility, seems almost as absurd as the statement that such inquiries lead of necessity to the denial of any higher power than that which in various forms is manifested as "force," on this small portion of the universe. It is almost as absurd, but not quite. For, surely, he who recognises the doctrine of the mutual convertibility of all forces, vital and physical, who believes in their unity and imperishableness, should be the last to doubt the existence of an all-powerful Being, of whose will they are but the various correlative expressions; from whom they all come; to whom they return.